



# Measurement of Emissions from Engines on Ocean-Going Vessels



**Air Resources Board  
Ocean-Going Ship Main Engine Workshop  
September 24, 2007  
Sacramento, CA**



# Discussion Topics

- Objectives
- Approach
- Results
- Current Work
- Discussion



# Objectives

- Measure the criteria pollutant emissions from ocean-going vessel main engines using the certification (ISO) cycles
- Measure emissions during typical operations, maneuvering, and vessel speed reduction modes



# Approach: Determining Emission Factors

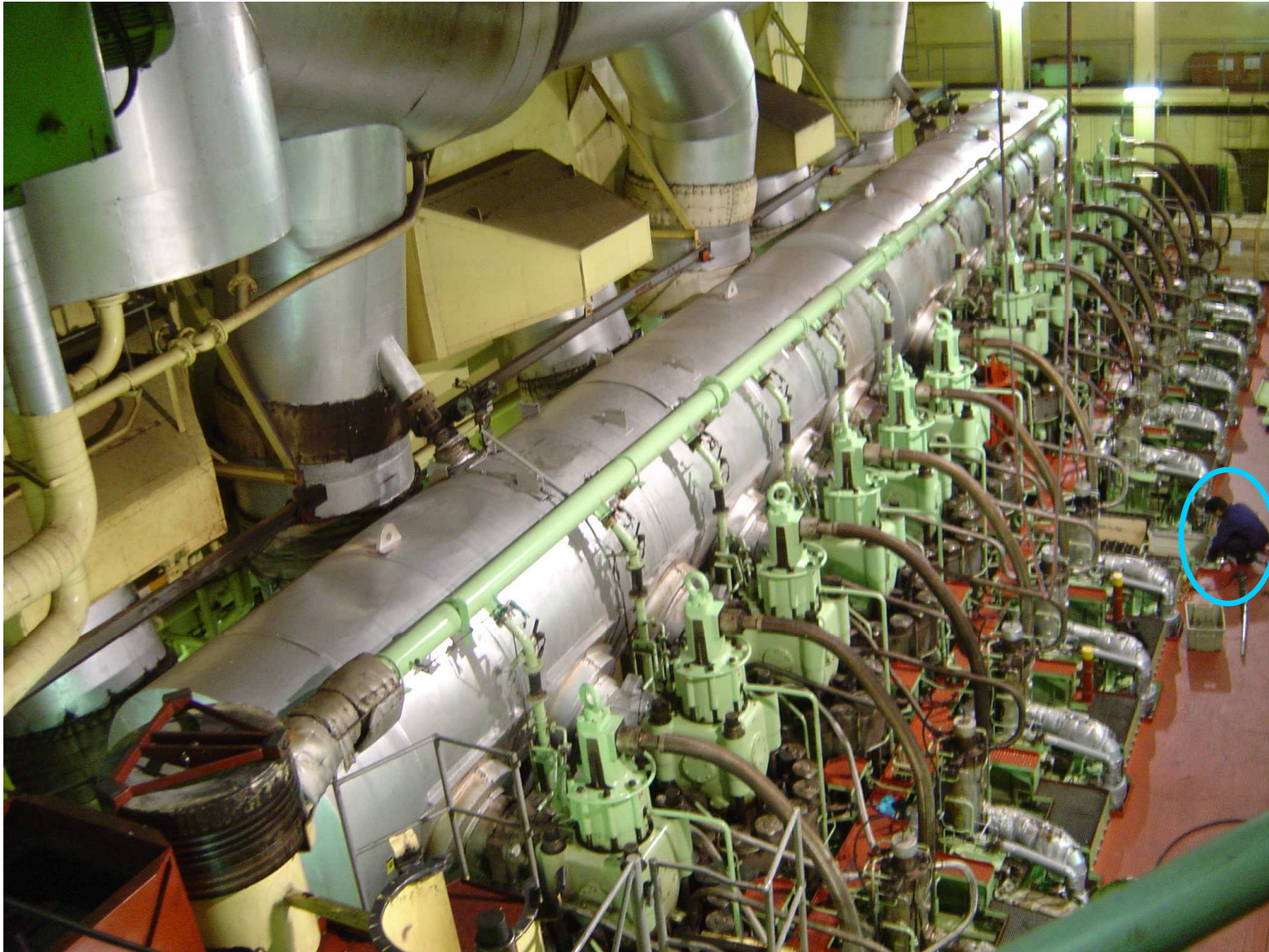
- Engine conditions
  - Follow ISO 8178-4 E3 marine cycle for comparison with other data.
  - Actual in-use operation.
- Gases monitored by ISO/EPA methods
  - NO<sub>x</sub> Chemiluminescence detector
  - CO, CO<sub>2</sub> Non dispersive infrared
  - HCs GC/FID
  - SO<sub>2</sub> Calculate from fuel
- Particulate matter (PM)
  - Use ISO 8178-1 partial dilution method &
  - real-time methods
- Emission factor determined from engine settings & calculated mass flow.



# Properties of Test Engines

Source	Manufacturer/Model	Rated Power (kW)	Technology
Main Engine (Suezmax tanker)	Sulzer 6RTA72	15,750	2-stroke
Main Engine (Panamax container ship)	MAN B&W 11K90MC-C	50,270	2-stroke







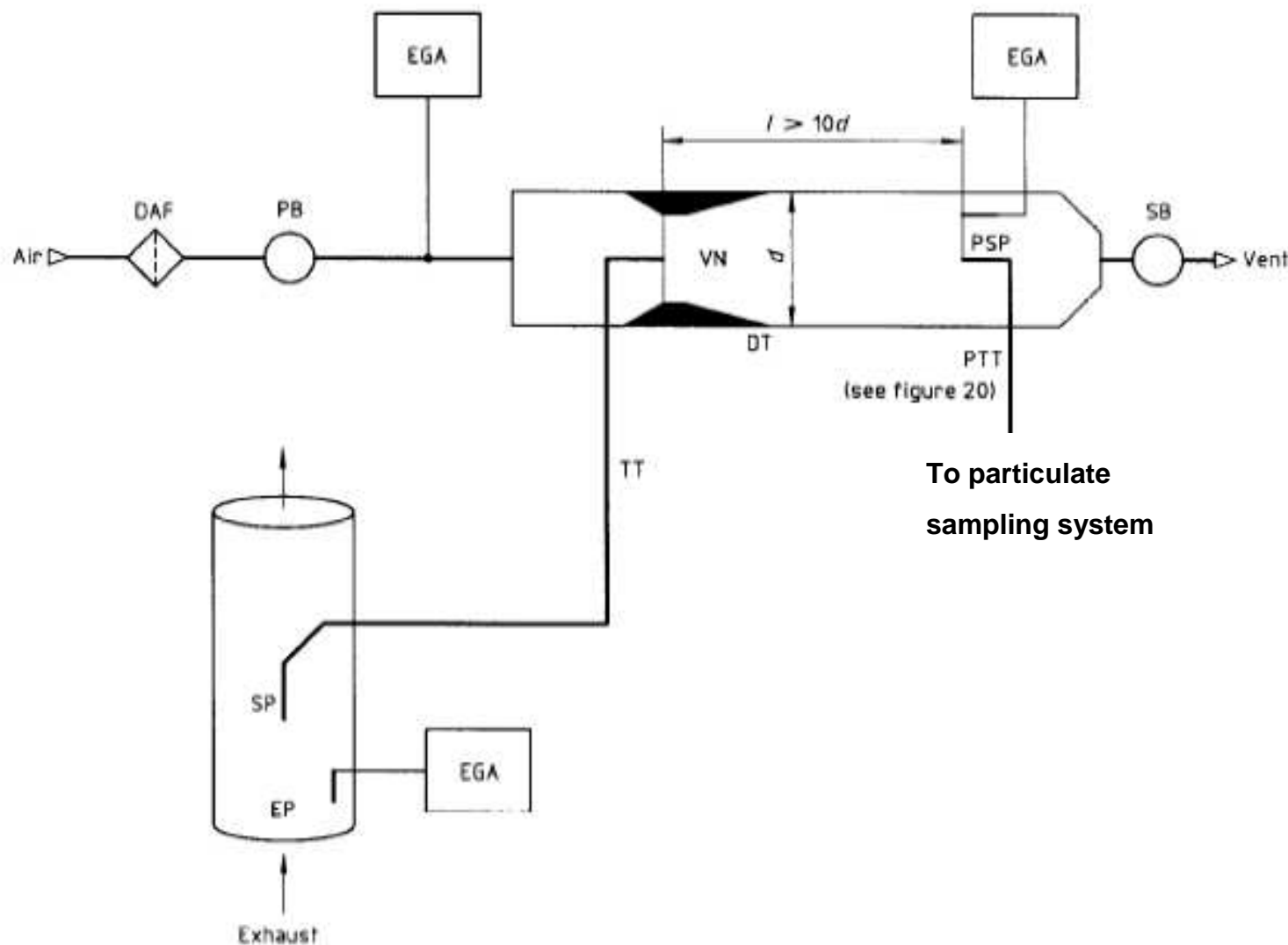
# Emissions from Main Engines

- Measurements made while engine operates per ISO 8178- E3 cycle with heavy fuel oil (HFO)
- Practical situations require working with the ship crew.

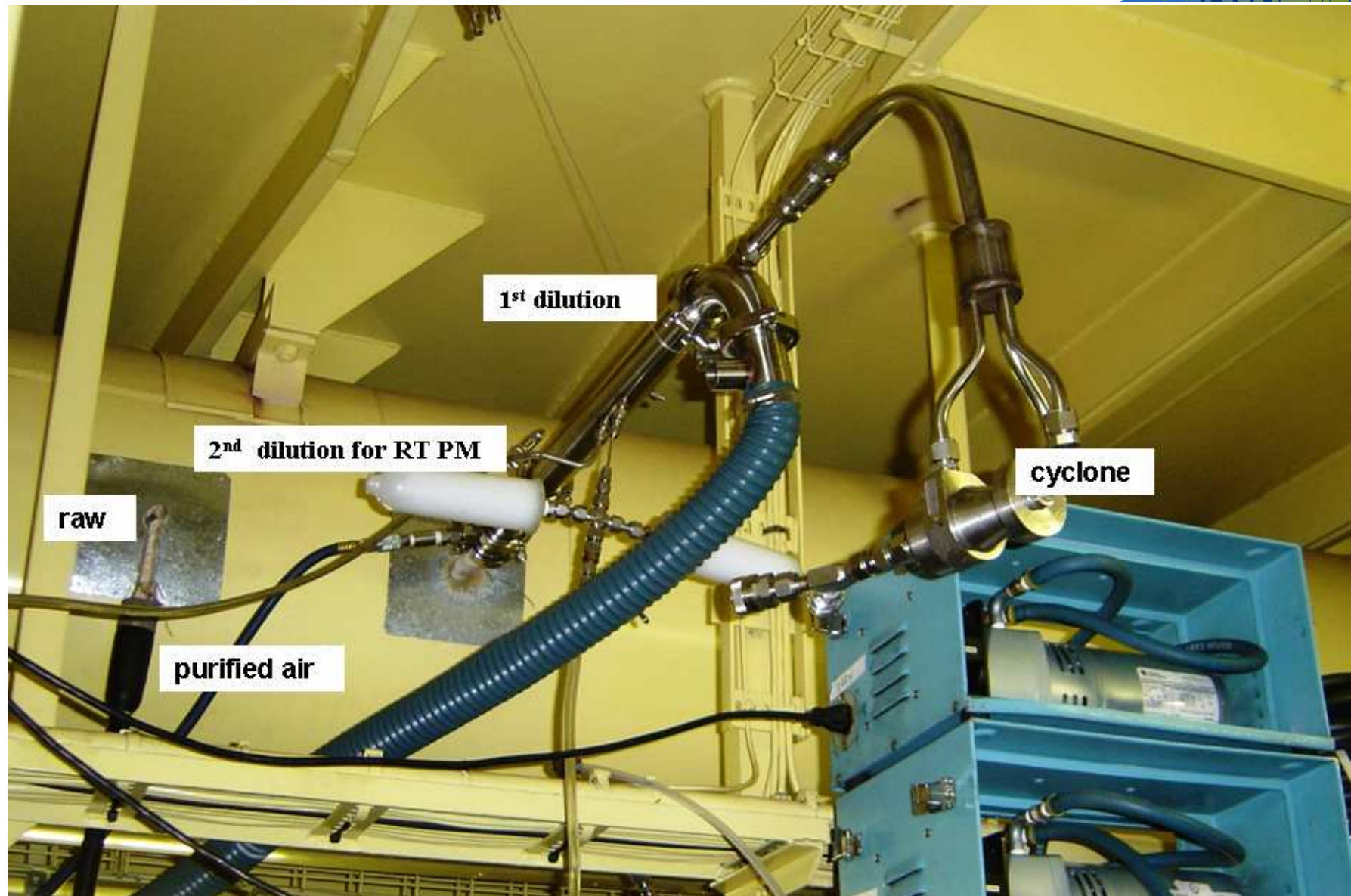
Mode number (cycle E2)	1	2	3	4						
Speed	Rated speed				Intermediate speed					Low-idle speed
Torque <sup>1)</sup> , %	100	75	50	25						
Weighting factor	0,2	0,5	0,15	0,15						
Mode number (cycle E3)	1				2	3	4			
Speed <sup>1)</sup> , %	100				91	80	63			
Power, %	100				75	50	25			
Weighting factor	0,2				0,5	0,15	0,15			

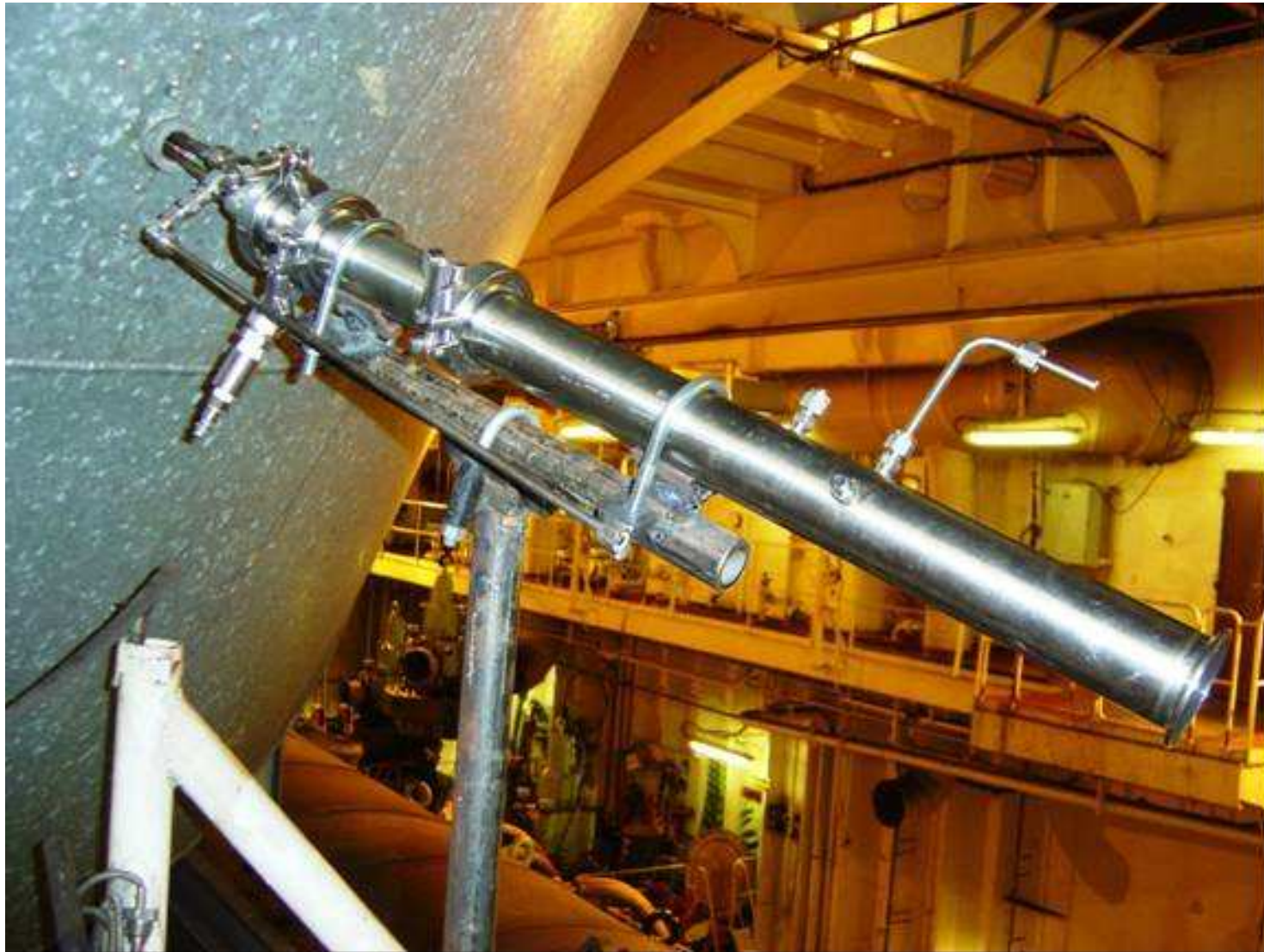


# Measuring Gases & PM with Partial Flow Dilution System with Single Venturi















# Results

Suezmax Main Engine

Panamax Main Engine



## Some Properties for Fuels Used in This Project

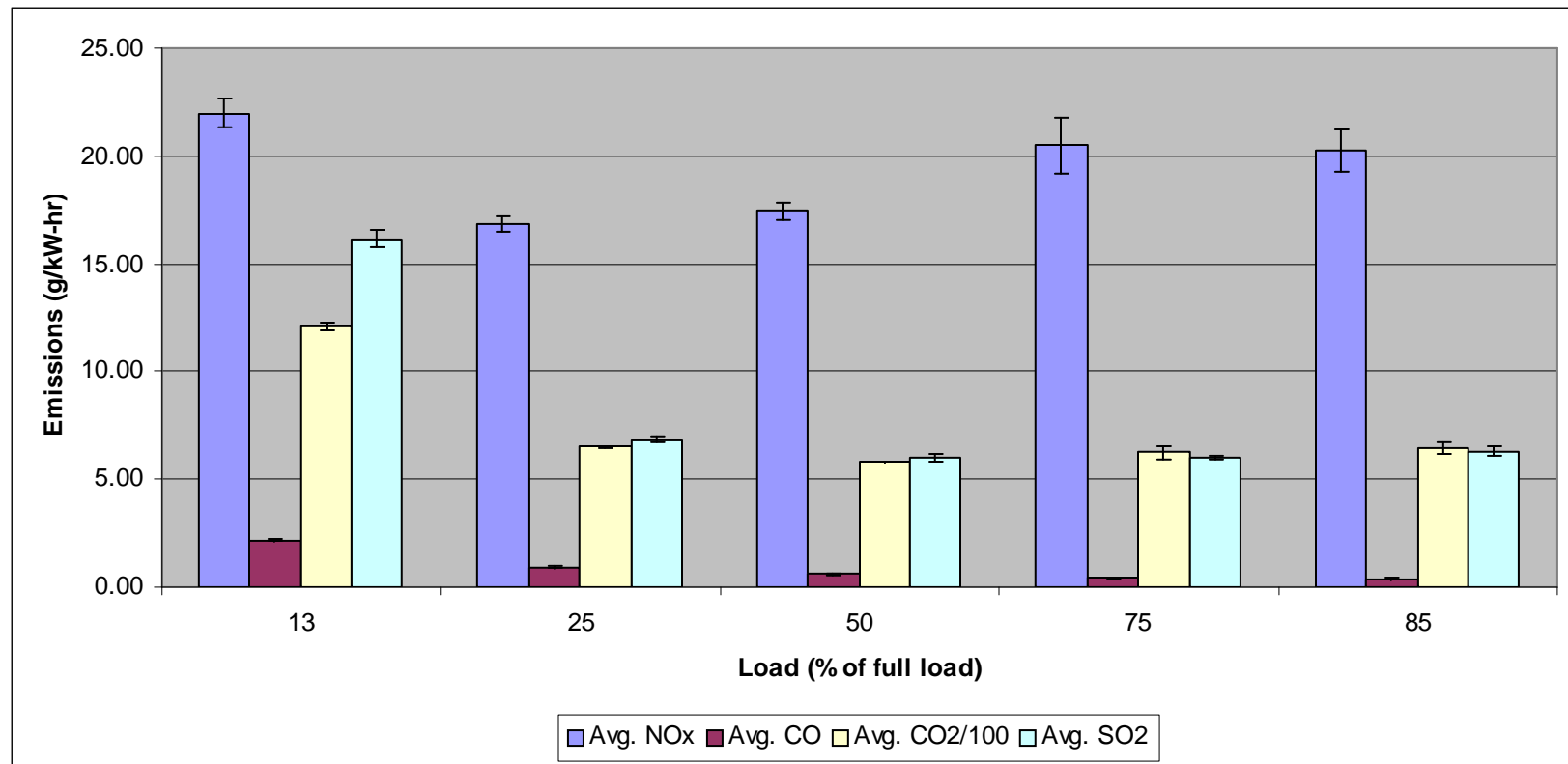
Fuel Property	HFO <sup>1</sup>	HFO <sup>2</sup>
Density (kg/M <sup>3</sup> ) @ 15 °C	989.7	990.8
Viscosity (cSt) @ 50 °C	230.6	296.8
Micro Carbon Residue (%m/m)	13	14.5
Sulfur (%m/m)	2.85	2.05

<sup>1</sup> Suezmax testing, Feb. 07

<sup>2</sup> Panamax testing, Sep. 06



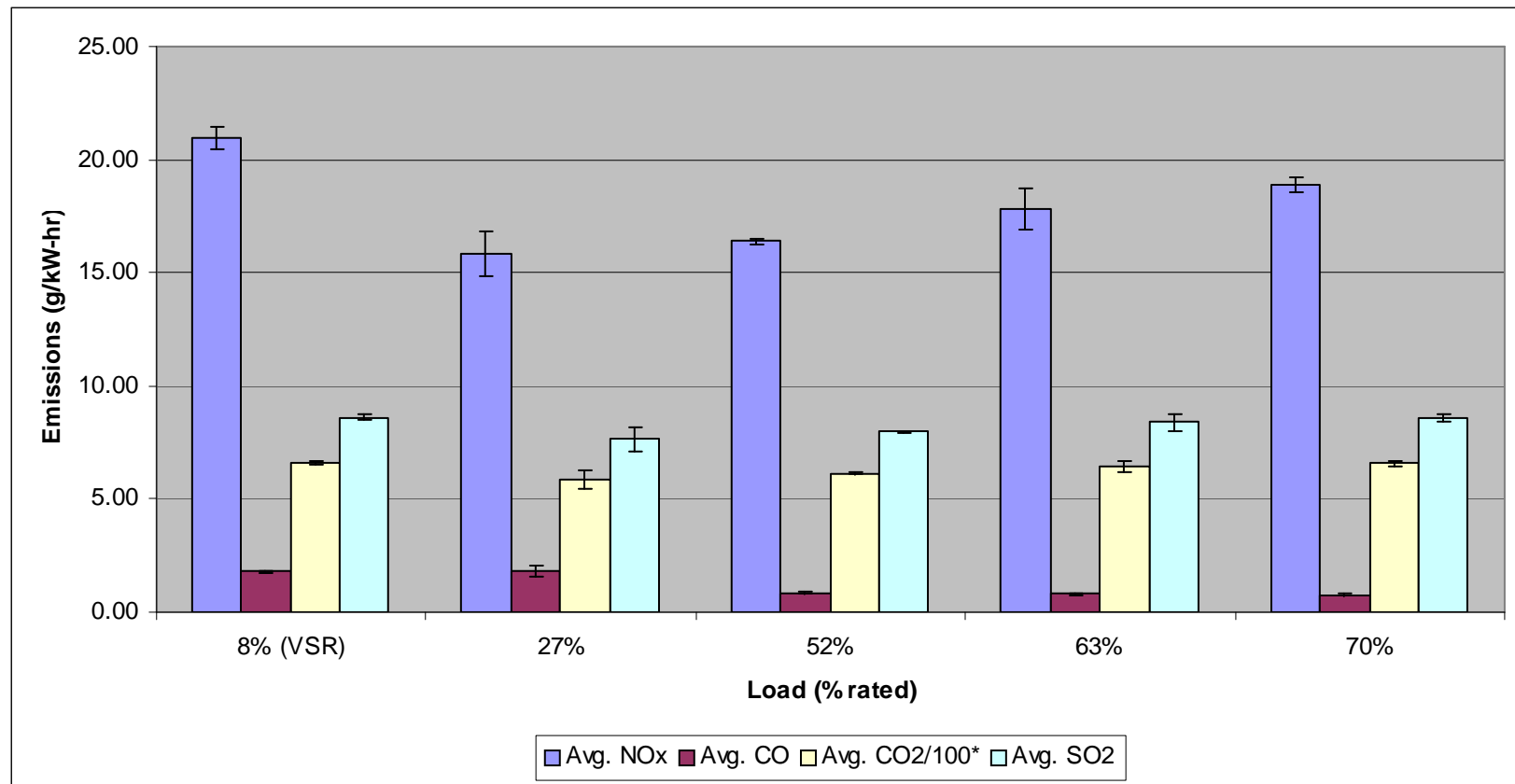
## Load-Specific Emission Factors (g/kW hr) for Different Gases from the Main Engine (Suezmax)





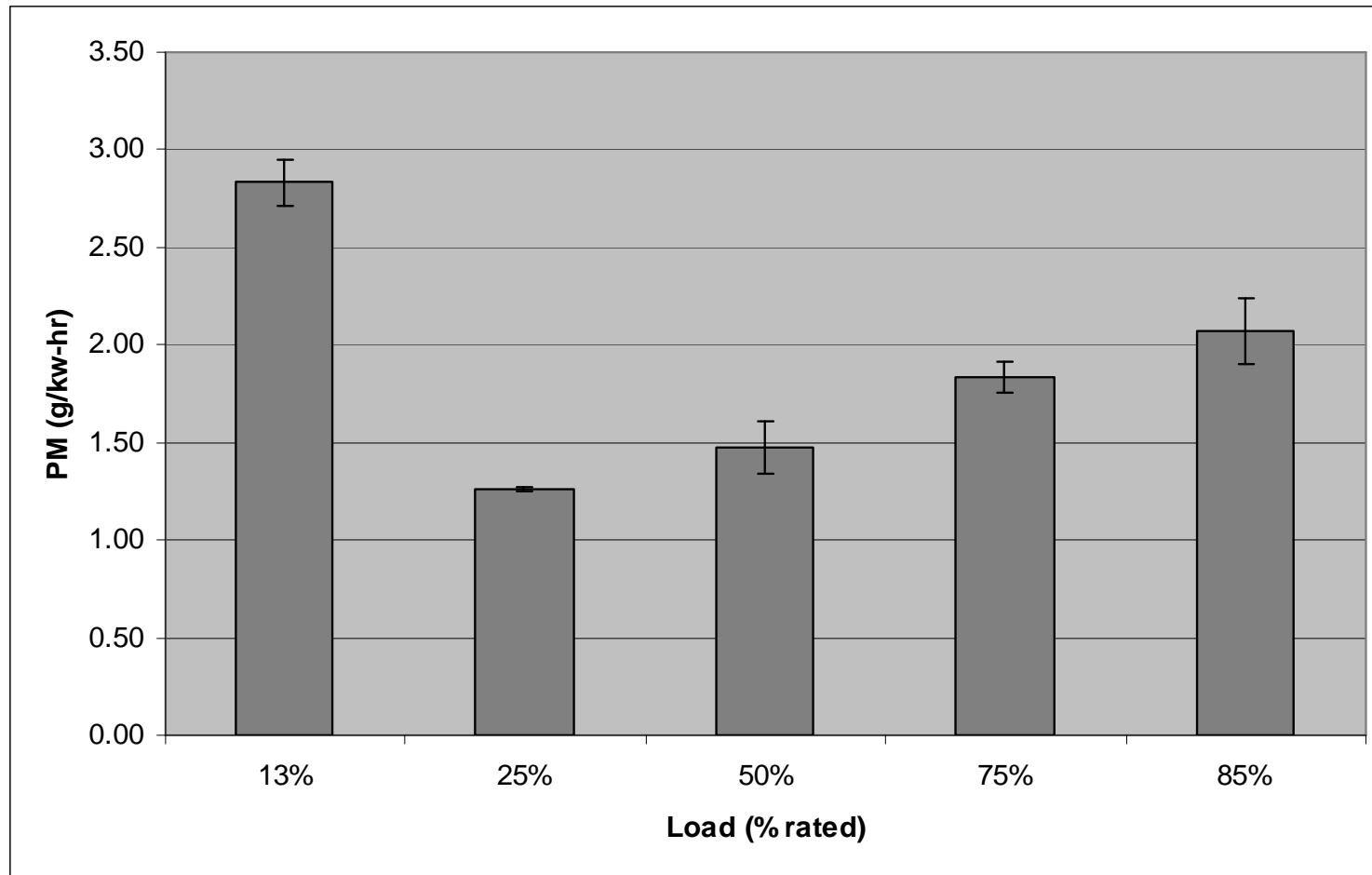


## Load-Specific Emission Factors (g/kW hr) for Different Gases from the Main Engine (Panamax)



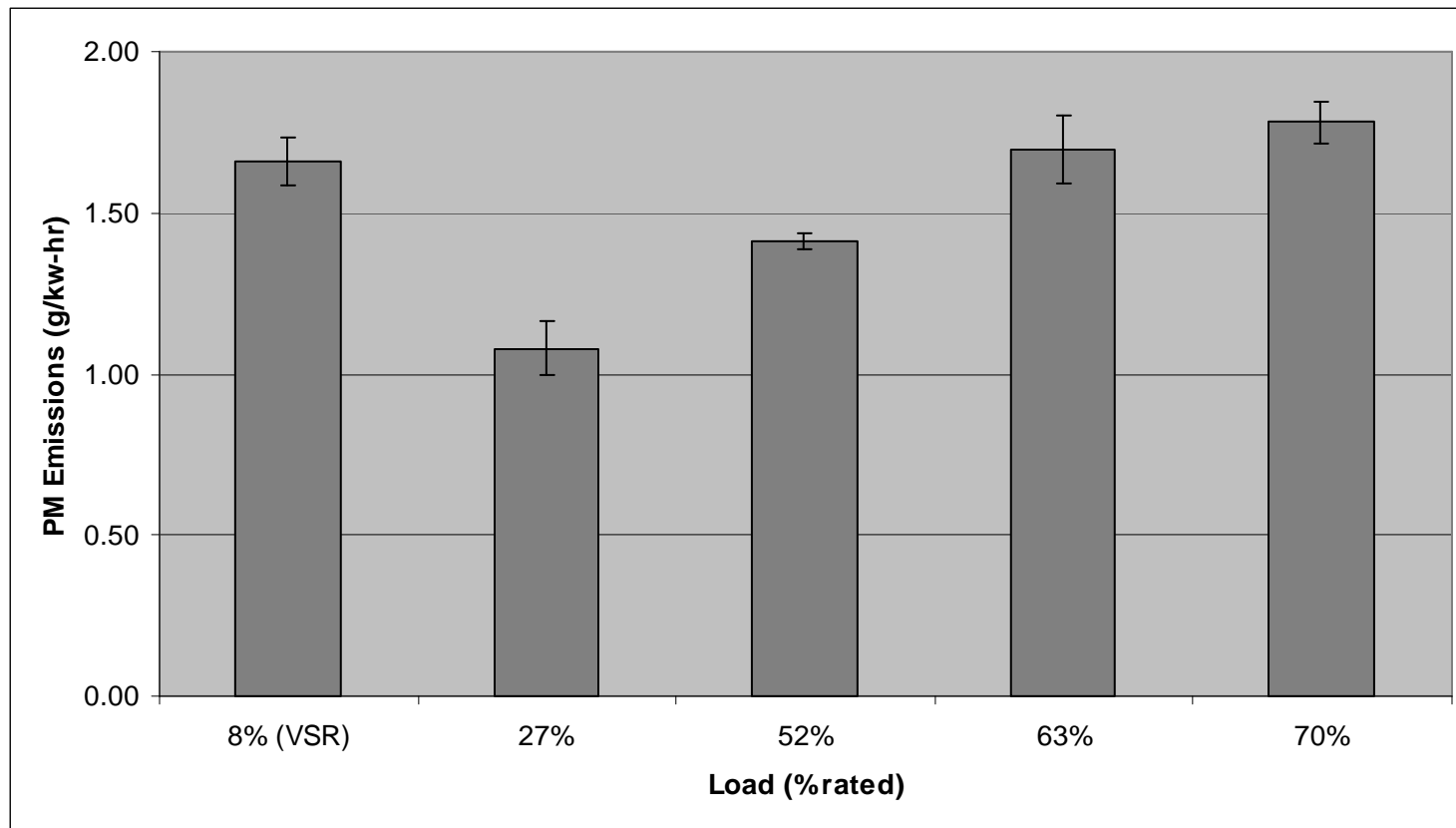


## Load-Specific Emission Factors (g/kW hr) for Particulate Matter Gases from the Main Engine (Suezmax)



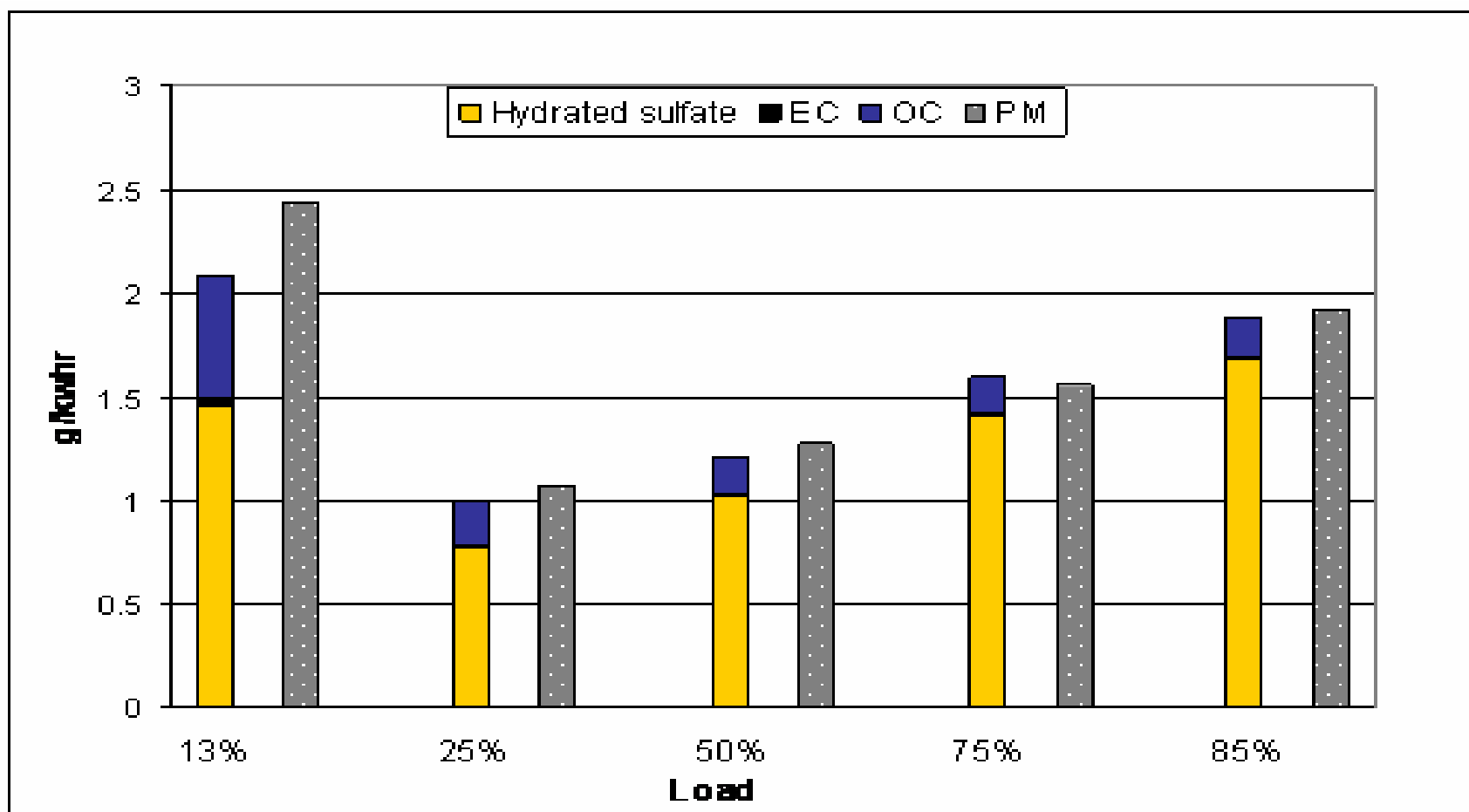


## Load-Specific Emission Factors (g/kW hr) for Particulate Matter Gases from the Main Engine (Panamax)



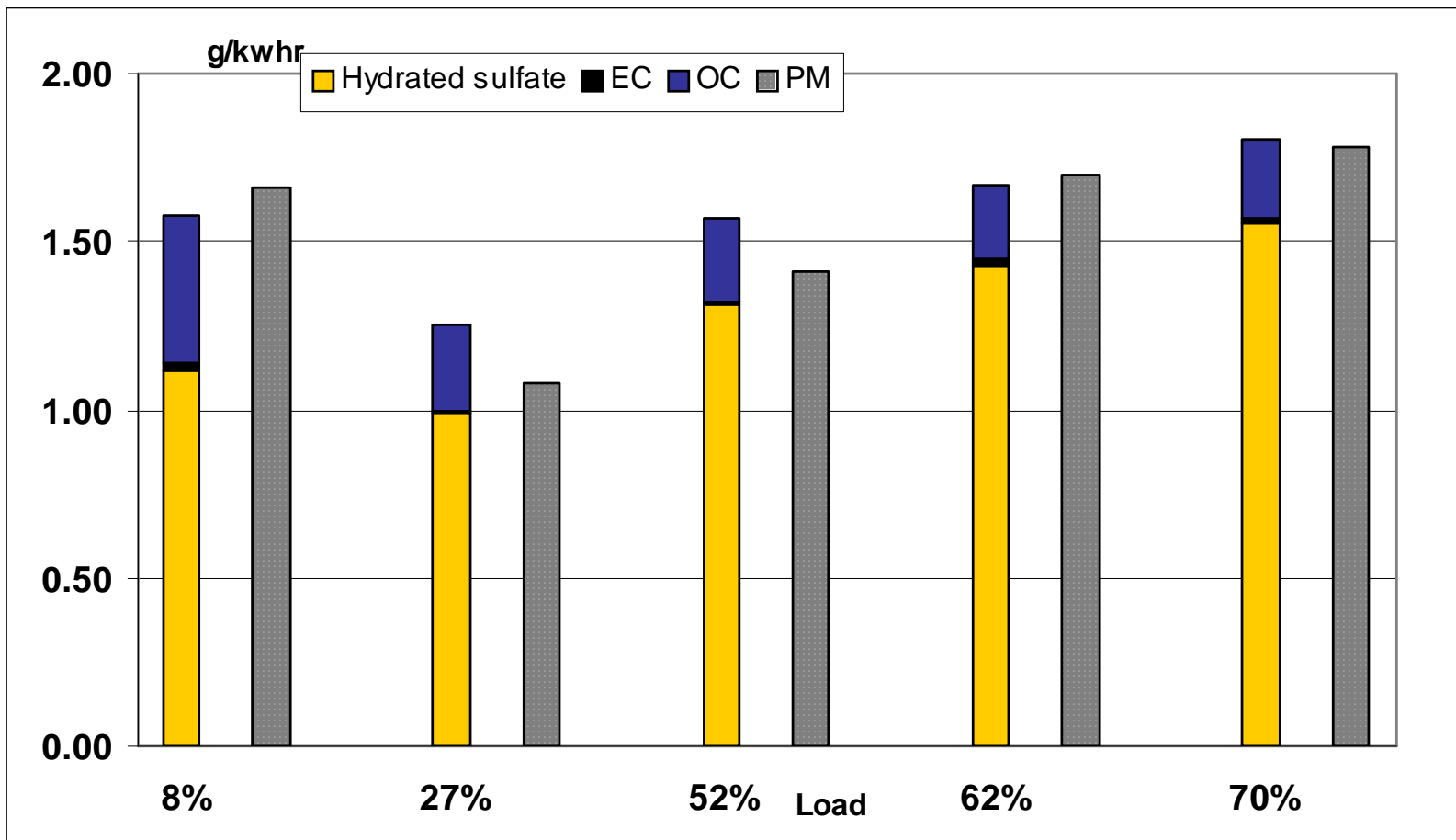


## Comparison of PM Mass with EC+OC+ Hydrated Sulfate Emissions (g/kW-hr), Main Engine (Suezmax)



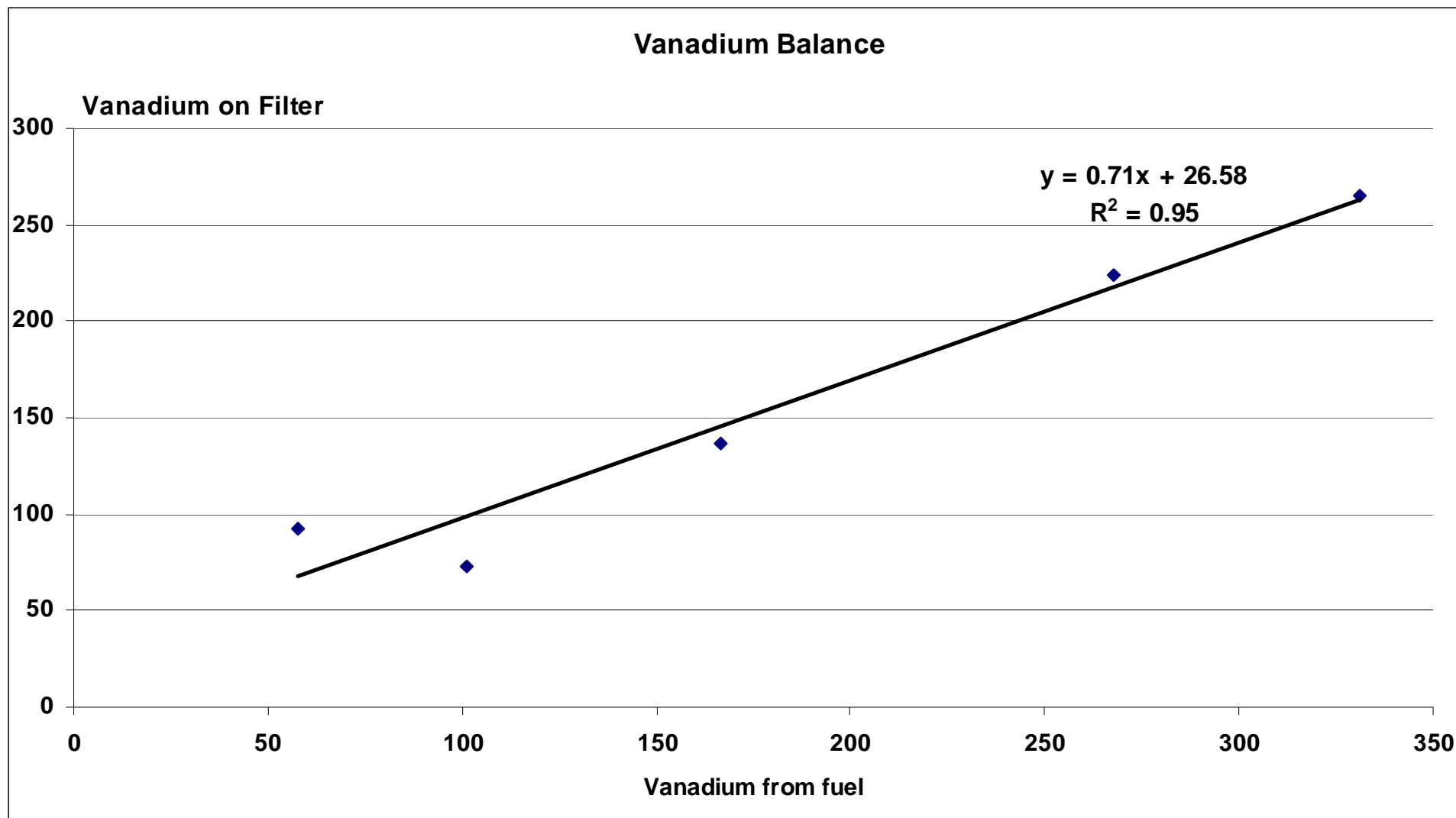


## Comparison of PM Mass with EC+OC+ Hydrated Sulfate Emissions (g/kW-hr), Main Engine (Panamax)





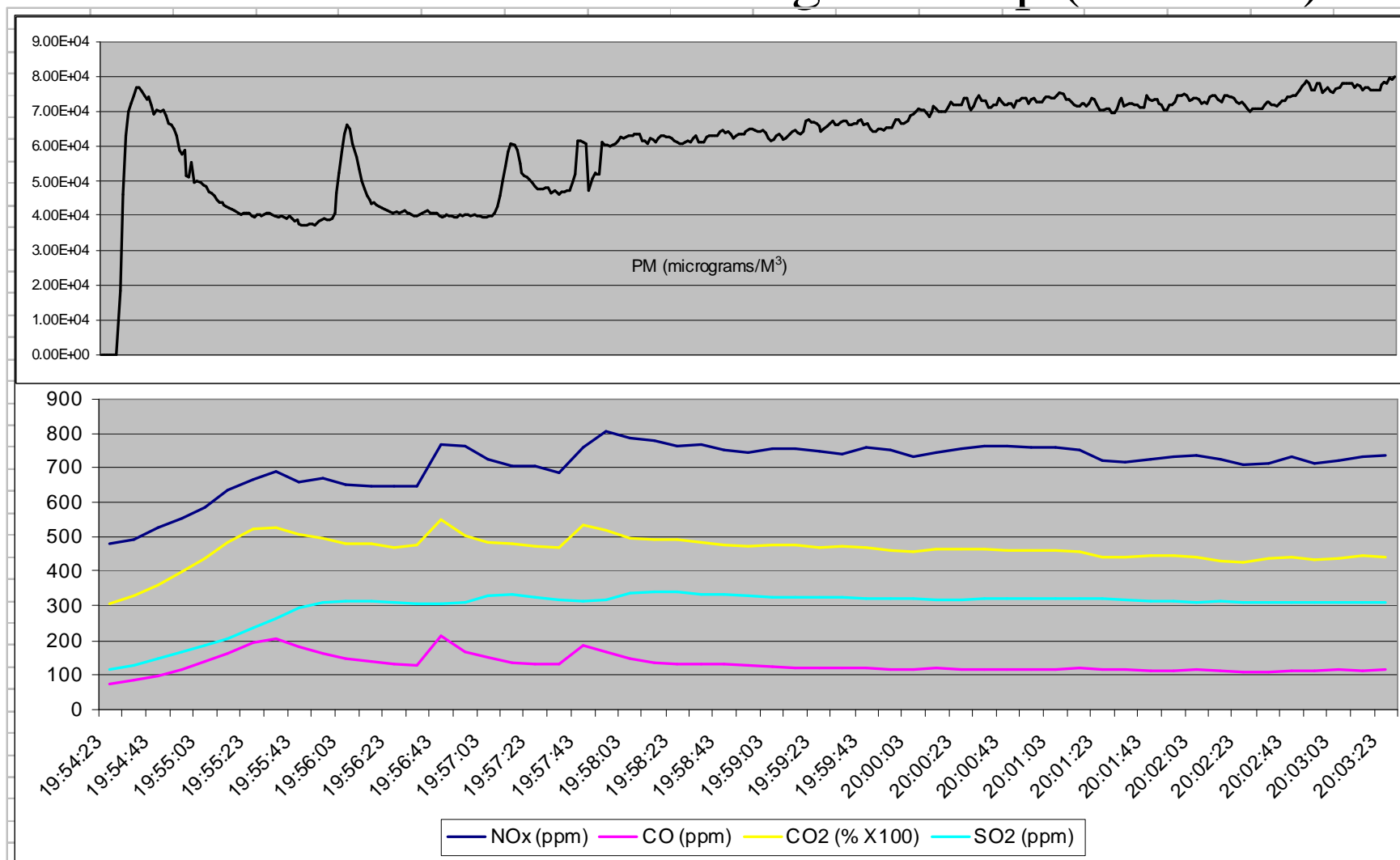
# Vanadium Balance





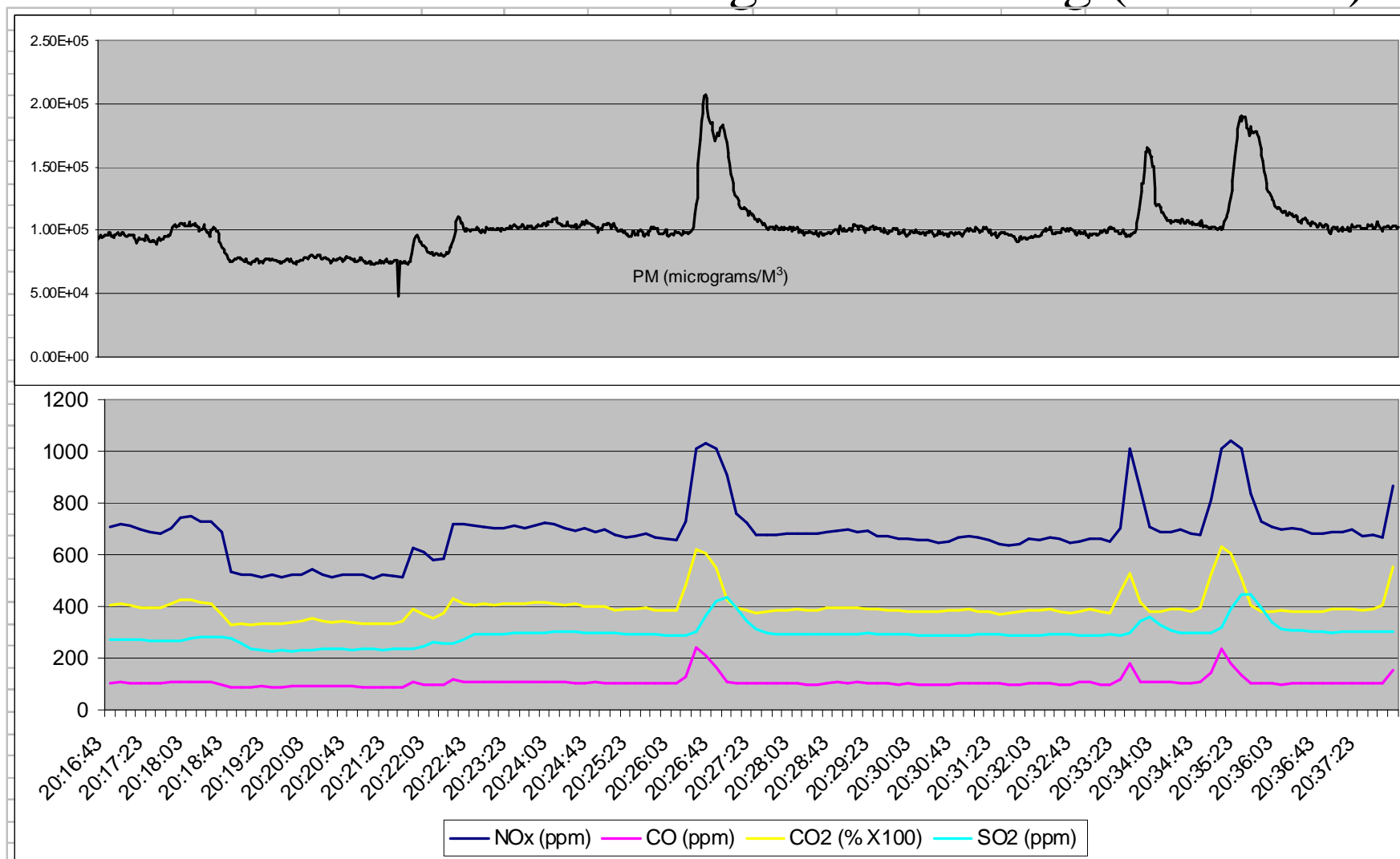


## Real-Time Emissions During Start-Up (Suezmax)





## Real-Time Emissions During Maneuvering (Suezmax)





# Current Work

- Assessing emissions from OGV main engines using low sulfur fuels [marine distillate oil (MDO) and marine gas oil (MGO)]
- Chemical characterization of PM as a function of particle size [emission inventories, dispersion models]
- Comprehensive testing of Panamax main engine using water/HFO emulsification system
- On-going development of OGV PM emissions measurement techniques [MOUDI, DMM, DusTrak, SMPS, TEM]
- Assessing emissions from auxiliary engines and boilers on ocean-going vessels



# Summary

- Developed suitable monitoring equipment for criteria pollutants and speciated fractions
- Gaseous emission factors are repeatable and match manufacturer values
- Independent measurements show total PM mass and sum of compositional masses are equal and agree with manufacturer's values
- On-going studies of fuels, PM characterization and sampling techniques



## *Thank You & Questions?*



Bill Welch  
[bwelch@cert.ucr.edu](mailto:bwelch@cert.ucr.edu)  
(951) 781-5743

Wayne Miller  
[wayne.miller@ucr.edu](mailto:wayne.miller@ucr.edu)  
(951) 781-5579